THE UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR ....DAISY THOMAS........

TITLE OF THESIS ..USE OF LOW GLUCOSINOLATE RAPESEED..

..MEALS IN RATIONS FOR LAYING AND..

..BROILER CHICKENS..

DEGREE FOR WHICH THESIS WAS PRESENTED ....M.Sc....

YEAR THIS DEGREE GRANTED ....1978....

THE UNIVERSITY OF ALBERTA

USE OF LOW GLUCOSINOLATE RAPESEED MEALS IN RATIONS FOR LAYING AND BROILER CHICKENS

by

© DAISY THOMAS

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

IN

Poultry Nutrition

DEPARTMENT OF ANIMAL SCIENCE

EDMONTON, ALBERTA

SPRING, 1978

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Use of low glucosinolate rapeseed meals in rations for laying and broiler chickens" submitted by Daisy Thomas, in partial fulfilment of the requirements for the degree of Master of Science.

This work is dedicated to the

memory of my late father

whose unfailing encouragement

helped me throughout

my educational career

ABSTRACT

Rations containing varying levels of low glucosinolate rapeseed meal (produced from Tower rapeseed) and high glucosinolate commercial rapeseed meal (produced from a mixture of Midas and Torch rapeseed) were fed to Shaver Starcross 288 laying chickens in order to determine the maximum levels at which these meals could be fed to laying hens without any adverse effects. The parameters studied included level of mortality, body weight, egg production, egg weight, egg quality, feed conversion, thyroid, spleen and liver weights, liver composition and incidence of fatty and hemorrhagic livers.

An experiment was also conducted to study the effects of varying levels of low glucosinolate rapeseed meals on performance of broilers. Meals from two varieties of rapeseed (Tower and Candle) were used in the study. Records were kept on level of mortality, growth, feed conversion, incidence of perosis and thyroid weight.

The use of rations for layers containing up to 15% of Tower RSM had no adverse effects on the traits studied other than causing a slight increase in the weight of the thyroid glands. The latter was considered unimportant since productive traits were not affected adversely. However, feeding rations containing 10 or 15% of high glucosinolate RSM to layers produced marked depressions in egg production, reduced egg Haugh unit values and

depressed final body weight. Thyroid weights were also markedly increased by feeding rations containing these levels of high glucosinolate meal.

The inclusion of 10, 20 and 30% of Tower or Candle RSM in rations for broilers had no adverse effects on mortality, body weight, feed conversion or incidence of perosis in broiler chicken at 4, 6 and 8 weeks of age. Thyroid size was also not unduly affected by any of the treatments.

The results of the studies suggest that up to 15% of low glucosinolate type RSM (produced from Tower rapeseed) may be safely included in the ration of laying hens and that up to 20% of low glucosinolate type RSM (produced from Tower or Candle rapeseeds) may be safely included in the ration of broiler chickens. Such levels of inclusion of high glucosinolate type RSM in rations for layers and broilers have been shown in this and many other studies to adversely affect productive traits and to cause greatly increased thyroid size.

ACKNOWLEDGEMENTS

The author wishes to thank, the Chairman of the Department of Animal Science, for placing the facilities of the Department at her disposal.

She also wishes to express her gratitude and sincere appreciation to, Dr. D.R. Clandinin, Professor of Poultry Nutrition for his invaluable assistance, guidance and criticism throughout the project and during the preparation of the thesis.

Thanks are also extended to Dr. A.R. Robblee, Professor of Poultry Nutrition for his advice and guidance and to Dr. R.T. Hardin, Professor of Poultry Genetics for assistance in the statistical treatment of the data.

Sincere thanks are extended to Mr. M.A. Pringle and Mr. J. Watson and other members of the Poultry Research Farm for the feeding and management of the experimental birds.

Technical assistance of Mrs. Jean Heard in removal of thyroids and the assistance of Miss Wendy Beaton in typing the manuscript are warmly appreciated.

Grateful thanks are also extended to my parents who have patiently encouraged me in my studies.

Financial support from the Rapeseed Association of Canada, and the Alberta Department of Agriculture is gratefully acknowledged.

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

Production of rapeseed in Western Canada has increased rapidly during the last twenty-five years. As a consequence of the expansion in acreage sown to rapeseed, Canada has become the world's largest exporter of this oil-rich seed. In addition, the availability of a large supply of rapeseed in Canada has made possible the development of an oilseed processing industry based primarily on rapeseed. The latter has proven important to Canada since it has made possible supplying about 30% of Canada's edible oil requirements from rapeseed oil and made available a large supply of protein-rich rapeseed meal (RSM) for feeding to livestock and poultry.

Early research on the use of Canadian-type RSM in rations for livestock and poultry showed that one of the main drawbacks to inclusion of high levels of this feedstuff in such rations was its relatively high glucosinolate content. This, coupled with the low metabolizable energy and low protein contents of RSM severely limited the levels at which the meal could be included in rations for livestock and poultry without adversely affecting the productive traits of the various kinds of livestock and poultry.

In an effort to improve the feeding value of RSM, plant breeders undertook development of varieties of rapeseed with low glucosinolate levels and high levels of oil and protein. As a result of the work of Canadian

plant breeders, two varieties of rapeseed have been developed which are low in glucosinolate content; one of which is also high in oil and protein contents; the other, high in oil content but with no improvement in protein content. These varieties are, respectively, called Tower and Candle.

It was speculated that moderately high levels of RSM produced from these two varieties could be used in rations for laying chickens and broiler chickens. The experiments reported herein were designed to determine whether levels of low glucosinolate type RSM in excess of those currently recommended for usage of high glucosinolate type RSM in rations for layers and broilers may be used without producing adverse effects on productive traits.

LITERATURE REVIEW

A. Nutrient Content of Rapeseed Meal

1. Protein and amino acids

In early work on the use of RSM in rations for poultry, Clandinin *et al*. (1959) reported that inclusion of commercial RSM as a replacement for soybean meal (SBM) in rations for growing birds depressed growth rate and reduced feed efficiency. The inferior performance noted appeared to be related to the effects of high temperatures employed during expeller processing The lysine content of the expeller meals was reduced by more than 25% as compared to meals subjected to less drastic heat treatment. In further studies Clandinin and Tajcnar (1961) found that in the expeller process only

sufficient heat should be applied in cooking and conditioning to permit reduction of oil content of the meal to about 6% if damage to protein quality as measured by lysine content was to be avoided. Kratzer *et al*. (1954) and Klain *et al*. (1956) noted that when expeller processed RSM was included in chick starter diets, lysine could be limiting. Clandinin (1967) compared RSM produced by the prepress solvent or solvent methods of oil extraction with that produced by expeller extraction and found a marked improvement in the lysine content of the RSM in the prepress and solvent processed RSMs as compared to expeller processed RSMs. Processors in Canada today have converted from expeller processing to prepress solvent or solvent methods of processing to obtain maximum oil yield with minimum risk of heat damage to the protein of the byproduct (Clandinin, 1966).

Clandinin and Bayley (1963) studied the effects of variety and growing conditions on the protein and amino acid composition of rapeseed. They observed that Polish rapeseed (*Brassica campestris*) had significantly lower levels of protein than Argentine rapeseed (*Brassica napus*). The Argentine types of rapeseed were significantly lower in lysine than the Polish types. They also found that the environment under which the rapeseed was grown had highly significant effects on the lysine, histidine, arginine, phenylalanine and leucine contents of the protein of the

seed. Bell and Jeffers (1976) studied the range in quality of RSM being merchandised to the Canadian feed trade. They found that the protein content of RSM averaged 35.5% and 36.9% for the *B. napus* and *B. campestris* RSMs respectively.

Summers *et al.* (1971) reported that failure of amino acid and energy supplementation of RSM diets to improve performance of hens could be due to an imbalance of amino acids in the protein of RSM. An improvement in performance of chickens fed diets containing autoclaved RSM supplemented with arginine and no response to lysine supplementation was recorded by Olomu *et al.* (1974) suggesting that arginine was the first limiting amino acid in heat damaged RSM. Leslie and Summers (1975) concluded that the amino acid arginine was limiting in RSM diets and hence caused an amino acid imbalance which was responsible for the poor performance of the birds.

Information on the availability of amino acids in RSM is limited and only a few studies have been reported. Tao *et al.* (1971), using digestibility trials as a means of testing availability of amino acids in RSM, found that the digestibility coefficients of 16 amino acids in RSM ranged from 44 to 72% and 63 to 80% for the apparent and true digestibility coefficients, respectively. Nwokolo *et al.* (1976) reported that the availability of amino acids in RSM varied from 89.4% to 95.9% with an average value of 91.9% with the exception of methionine which was only 78.4%

available. The essential amino acids showed relatively high availability although most were significantly lower than in SBM.

2. Minerals

Giovannetti and Bell (1971) investigated the chemical composition of samples of *B. campestris* and *B. napus* RSMs from various parts of Canada. They noted a considerable range in the mineral contents of the various meals. They reported an average ash value of 8% and concluded that variation in mineral content was influenced by the mineral content of the soils in which the rapeseed was grown. They also found that the type of processing the meals had undergone had no significant effect on the mineral content of the meals. Bragg (1974) also reported similar variations in the mineral content among different RSMs.

The minerals in RSM are chiefly potassium, calcium, magnesium and phosphorus. They remain in the meal after extraction of the oil (Persmark 1972). Clandinin *et al.* (1972a) compared the levels of minerals in RSM with those in SBM. The values listed showed that RSM contained approximately twice as much phosphorus and almost 8 times as much selenium as in SBM. RSM was also a better source of zinc and magnesium and contained less potassium than SBM. Bragg (1974) observed that RSM was a particularly good source of biologically available selenium.

Motzok (1974) reported values ranging from 1.10 to 1.28% as total phosphorus content of RSMs from different strains of Span var. rapeseed. He also found the phytin phosphorus in

the same samples to vary from 0.42% to 0.78% i.e. about 34 to 71% of the total phosphorus present.

Clandinin and Heard (1968) reported that RSM contained about 3% tannins. Since tannins have been found to form complexes with metal ions (Jurd and Giessman, 1956), in vitro studies were conducted (Seth _et al_., 1975) to determine the zinc binding capacity of RSM, RSM fractions and of RSM from which the more soluble tannins had been removed. It was noted that RSM had a greater zinc binding capacity than SBM which was probably due to the tannin content or some unidentified factor(s) in RSM. Poor availability of zinc from diets containing rapeseed protein concentrate when fed to young rats was the major factor limiting growth and development (Momcilovic and Shah, 1976). Motzok (1976) recorded that additional zinc is required with RSM for maximum growth.

In the most recent analysis of the mineral content of _B. campestris_ carried out by Finlayson (1977) an ash content of 4.5% to 6% was reported. It was suggested that the mineral content of the seed depends to a certain extent on the mineral elements present in the soil in which the plant grows. On soils of low calcium the level of calcium in the plant would be reduced. Plants grown on low sulfur soil had reduced glucosinolate and methionine concentration.

3. _Vitamins_

Klain _et al_. (1956) reported that RSM contained about 3 times as much choline and approximately 10 times as much

niacin as SBM and suggested that the relatively high niacin content of the RSM was no doubt related to its high crude fibre content. Josefsson (1972) found that although the niacin content was higher in RSM when compared to SBM, the pantothenic acid, riboflavin and thiamine contents were similar.

4. Energy

Studies on the metabolizable energy (ME) value of RSM have been carried out by Sibbald and Slinger (1963) who reported that for chicks the 'corrected' ME of solvent extracted RSM was about 1530 kcal/kg on an air-dry basis. A higher value of 2120 kcal/kg for the 'corrected' ME of RSM on an air-dry basis was reported by Sell (1966).

Lodhi *et al*. (1969a) conducted a study to determine the ME value of RSM for chicks and hens and as to whether or not the ME value of RSM was affected by the length of time the birds had received RSM prior to the time at which the ME determinations were made. It was found that the ability of chicks to utilize RSM increased with age. It was also observed that the ME content of RSM for chicks 4 weeks of age and for hens increased when the measurement was made after the birds had been fed rations containing RSM for 26 and 19 days respectively. This length of time on rations containing RSM probably allowed compensatory changes in the thyroid glands of the chickens to occur and a return to normal output of the thyroid hormone.

The major factors reported to contribute to the low ME value of RSM when compared to SBM were the lower protein content, lower digestibility of protein, higher fibre content and lesser availability of carbohydrates in RSM (Lodhi et al., 1969b). Rao and Clandinin (1972) confirmed that low protein content, low absorbability of nitrogen and low availability of carbohydrates in RSM were responsible for its low ME value. The presence of goitrin in RSM however was not found to affect the ME value of RSM (Lodhi et al., 1970; Rao and Clandinin, 1970).

Clandinin et al. (1972a) recommended an ME value of 1760 kcal/kg (as-fed) for RSM for poultry. However, recent values reported would suggest that an ME value of at least 1900 kcal/kg (as-fed) should be assigned when calculating ME values of the new low glucosinolate varieties in rations for poultry (Clandinin et al., 1977).

Seth and Clandinin (1973a) separated RSM into two fractions, one of low hull and high protein and the other of high hull and low protein contents. The low hull fraction was found to contain 25% more and the high hull fraction about 25% less ME than the whole RSM. This supports the work of Lodhi et al. (1969b) who mentioned previously that low ME value of RSM were probably due to high fibre contents in the meal.

B. Use of Rapeseed Meal in Rations for Layers

1. Level of usage

Fangauf and Haensel (1938) recommended that not more than 10% RSM be used in diets for layers while Frolich (1952) found that fairly low levels of RSM in the diets of hens caused a decrease in the laying performance.

Jackson (1969) conducted an experiment to investigate and compare the effects of including RSM up to a level of 20% in the diets of two modern hydrid strains of caged laying hens. A marked breed difference in level of mortality was observed in the two strains of pullets that were fed RSM containing diets. The medium-weight hybrid birds were more tolerant to RSM than the light-weight Hyline birds. He found that satisfactory egg production with no increased mortality was obtained with up to 16% RSM in the diet of the medium-weight hybrid strain of birds while a marked decrease in egg production occurred when 8% RSM was included in the diet of the Hyline layers. In a further study Jackson (1970) tested the level of Algerian and French RSM which could be included in laying rations and found that 8 and 6.9% respectively in the diet gave satisfactory egg production.

Canadian nutritionists recommended a 5% level of high glucosinolate Canadian-type RSM for layers, higher levels were found to cause increased mortality, reduced egg production and reduced egg size (Clandinin *et al.*, 1972b).

Marangos and Hill (1976) studied the effects of RSM (from *B. napus* and *B. campestris* rapeseed) and mustard seed meal (from *Brassica juncea* mustard seed) in laying rations at the level of 12%. They concluded that *B. napus* type RSM should not be used in layers' diet while *B. campestris* and *B. juncea* type meal did not appear to have any detrimental effects on performance. Clandinin *et al*. (1976) have reported that low glucosinolate type RSM from *B. napus* var. Tower may be included in laying rations at the 10% level of inclusion without adversely affecting productive traits. Comparison of feeding rations containing high glucosinolate RSM and low glucosinolate RSM to layers (Smith and Campbell, 1976) revealed that high glucosinolate RSM depressed egg production more than the low glucosinolate RSM.

2. Problems associated with usage of Rapeseed meal

i. Goitrogenicity

Marked enlargement of the thyroids of rats fed diets containing 45% of seeds of the Brassica family was reported by Kennedy and Purves (1941). Petit *et al*. (1944) and Turner (1946) were the first to point out that the feeding of RSM and rapeseed respectively to chickens caused enlarged thyroids and depressed growth. Later Turner (1948) showed that the goitrogenic agent present in rapeseed was contained in the rapeseed oil cake meal rather than in the rapeseed oil. Clandinin and Bayley (1960) showed that in

laying hens fed RSM the glands exhibited enlargement due to increased number of follicles. The central portion of the glands eventually became distorted, filled with cells and a reduced colloid content was noted.

Goitrogenic substances which are biologically inactive occur in the seed of Brassica species in the form of thio-glucosides which upon hydrolysis by the enzyme myrosinase yields 2-hydroxy-3-butenyl isothio-cyanate (Greer, 1956; Virtanen, 1965; Van Etten et al., (1969). It was noted (Kjaer, 1960) that this compound is unstable and cyclizes to the antithyroid substance, (-)-5-vinyl-2-oxazolidinethione (OZT). Van Etten et al. (1969) and Rutkowski (1971) reported that in addition to the above other isothiocyanates and nitriles are also produced. The relative amounts of the products liberated by myrosinase vary depending upon the pH of the hydrolysis medium (Daxenbichler et al., 1966). Until low glucosinolate RSMs were developed, two general types of rapeseed were being produced in Canada, *B. napus* (Argentine rape) and *B. campestris* (Polish rape). The latter has been reported to have less glucosinolates than the former and hence less goitrogenicity (Renner et al., 1955; Klain et al., 1956; Clandinin et al., 1959).

Clandinin et al. (1966) studied the effect of feeding synthetic goitrin, (OZT), on the uptake and release of radioactive iodine from the thyroid glands. It was

observed that inclusion of goitrin resulted initially in suppression of iodine uptake by the glands and reduced secretion of thyroxine. Continued feeding of goitrin resulted in compensatory changes occurring in the thyroid glands and a return to normal thyroxine secretion.

The isothiocyanate (ITC) and OZT liberated by myrosinase from their parent thioglucoside in RSM, are known to act differently on the thyroid gland at the cellular level (Greer *et al*., 1964). Marangos and Hill (1975) reported OZT to be a much stronger goitrogen than ITC and therefore *B. napus* RSM was considered to be more goitrogenic than *B. campestris* RSM.

The mechanism of action of OZT on the thyroid gland is not completely understood. However, it is known that OZT blocks the irreversible mechanism connected with the organic binding of iodine in the thyroid gland and thus a partial suppression of thyroxine synthesis follows (Rutkowski, 1971). Clandinin *et al*. (1966) showed that initially high levels of OZT in the diets of chickens resulted in depressed growth rate and thyroid enlargement and decreased uptake of radioactive iodine. However, after some time, the uptake of radioactive iodine became normal showing that the chicks had eventually reached a physiological equilibrium at increased thyroid to body weight ratios. Similar observations were made by Akiba and Matsumoto (1973). Roos and Clandinin (1975) observed that

there were enlarged thyroids in chicks hatched from eggs laid by breeding hens fed diets containing RSM because the smaller amounts of iodine transferred to the egg did not permit the thyroid glands of the chicks to develop normally during the incubation period. Further studies on transfer of ^{125}I to egg (Goh and Clandinin, 1977) indicated that the amount of ^{125}I transferred to egg yolk was significantly reduced by the inclusion of high glucosinolate RSM in the laying rations. The reduction in iodine content in egg yolk was less severe when low glucosinolate RSM was included in the diet.

ii. Fishy eggs

Recently in Britain many egg producers received complaints concerning an unusual 'fishy' odor in some of their brown shelled eggs (Miller et al., 1972). This odor was associated with RSM which was included in the laying rations.

'Fishy' taint was first described by Vondell (1932) who found it in eggs laid by Rhode Island Red hens. Later Vondell (1948) also found similar egg taints in eggs from New Hampsire hens and Barred Plymouth Rock hens. Vogt et al. (1969) reported on an unusual odor in white shelled eggs with as little as 8% RSM in the diet.

Hobson-Frohock et al. (1973) was the first to report that the fishy odor resulting from the inclusion of RSM in the ration of layers was due to the presence of trimethylamine (TMA). That the incorporation of RSM in the

laying diets increased the incidence of 'fishy' eggs and that the incidence increased as the level of RSM in the diet increased was shown by Overfield and Elson (1975). Later Hobson-Frohock _et al_. (1975) reported that 'fishy' eggs occurred more in brown shelled eggs than in white shelled eggs and only a proportion of birds in flocks laying brown eggs were affected. They concluded that the ability of the bird to metabolize TMA which was responsible for the fishy odor was genetically controlled. Bolton _et al_. (1976) confirmed the above findings and reported that tainting was conditional on the presence in the hen, in the heterozygous or homozygous state of an autosomal semi-dominant gene that has variable expression depending on environmental factors.

At present, research is being conducted to identify the factor(s) in RSM which is responsible for this problem. Once this is known it is possible that plant breeders could eliminate it from rapeseed.

iii. _Hemorrhagic liver syndrome_

Feeding of RSM to laying chickens has been restricted due to an increased incidence of hemorrhagic liver syndrome (HLS) resulting in high mortality rates. Jackson (1969) fed varying levels of RSM (0 - 20%) in laying rations and found that the main cause of death was hemorrhage of the liver. Hall (1972) reported on severe losses in heavy breeds of chicken due to hepatic hemorrhages. It was

suggested that the hemorrhages were caused by lysis of the reticular substance of the liver by unknown toxins which weakened the structural strength of the liver. He also suggested that the hemorrhages probably occurred along with the transitory rise in blood pressure that occurs when a bird is about to lay an egg. It was concluded that the use of RSM was associated with the occurrence of HLS. Similar observations were also made by Hall (1974) and Yamashiro *et al*. (1975).

Hill and Marangos (1974) observed that mortality due to HLS was higher in those birds fed *B. napus* rather than *B. campestris* type RSM. Although the OZT content of *B. napus* meal was higher than that of *B. campestris* meal, HLS could not be attributed to OZT since *B. juncea* meal which has no OZT caused a higher incidence of HLS. March *et al*. (1975) and Olomu *et al*. (1975), also observed increased mortality from HLS in layers fed high levels of RSM.

Clandinin *et al*. (1974, 1977) demonstrated that in addition to level of RSM in the ration, the incidence of HLS and level of mortality was influenced by the strain or breed of chicken used. Slinger (1976a) made similar observations and reported that Hyline 934E birds were more susceptible to this condition than the Shaver Starcross 288 birds. In a later study Slinger (1976b) reported that Hyline W-36 birds were not as susceptible to

this condition as the Hyline 934E birds had been.

C. Use of Rapeseed Meal in Rations for Broilers

1. Level of usage

Some variability in recommended maximum levels of usage of RSM have been observed. Inclusion of very high levels of RSM in broiler diets (Vogt et al., 1967; Vogt and Schubert, 1969) resulted in reduced weight gain and decreased efficiency of feed utilization. They recommended that not more than 10-12% of RSM be included in diets of broiler chickens. The results of other studies (Clandinin and Robblee, 1966; Clandinin et al., 1972) suggested that levels of RSM as high as 15% of the ration may be included in broiler rations as a replacement for SBM. Although thyroid to body weight ratios were slightly higher in the chickens fed RSM containing rations than in those fed the SBM control ration, the growth and feed conversion of chickens were not affected by the use of RSM.

When the dietary level of energy and protein were controlled Nakaya et al. (1968) reported that a 10-20% level of RSM could be used as a replacement for SBM in broiler finisher diets. Recently Marangos et al. (1974) concluded that 10% or possibly more RSM could be included in broiler rations without significant depression of growth rate.

The advent of the new low glucosinolate varieties of RSM may lead to some modification in recommended levels of usage. Clandinin et al. (1976) observed that up to 20%

RSM from the low glucosinolate variety, Tower, may be included in rations of broilers without affecting their body weight or feed conversion. In studies involving comparisons of high glucosinolate RSM (Span) and low glucosinolate RSM (1788) Slinger (1976b) found that levels as high as 20% and 40% of the low glucosinolate RSM could be used in chick rations without affecting growth or feed conversion adversely or increasing the size of the thyroid glands appreciably over the size of the thyroid glands of those chickens fed rations based on SBM. These results suggest the feasability of using high levels of commercially available low glucosinolate type RSM in rations for broilers.

2. Problems associated with usage of Rapeseed meal

i. Goitrogenicity

Goitrogenic properties attributable to components of RSM were first reported by Kennedy and Purves (1941) in a study with young rats. Enlarged thyroids occurred even though the diet contained an adequate level of iodine. Other studies indicated that some alleviation of the problem could be attained by supplementing the diets with higher levels of potassium iodide (Purves, 1943; Allen and Dow, 1952), or by inclusion of iodinated casein (Blakely and Anderson 1948; Kratzer *et al*., 1954). Dow and Allen (1954) concluded that provided sufficient iodide was present RSM could be substituted for SBM in broiler rations.

Several authors have studied the effect of goitrogens in poultry (Turner, 1946, 1948; Petit *et al*., 1944; Clandinin and Bayley, 1960). OZT one of the hydrolytic products of glucosinolates in RSM has been found to be mainly responsible for the enlarged thyroid (Astwood *et al*., 1949; Clandinin *et al*., 1959). Clandinin *et al*. (1966) noted that when synthetic OZT was fed to the chicks the initial uptake of iodine was greatly reduced and colloid stores in the thyroid glands were depleted. This was followed by hypertrophy and hyperplasia of the gland and increased iodine uptake. A physiological equilibrium was reached at increased thyroid to body weight ratios after the chickens had received OZT for 25 days. Yoshida *et al*. (1969) noted a similar biological equilibrium of thyroid to body weight ratio by 4 weeks on Canadian meals, but this was not true of meals produced in Japan.

ii. Perosis

A serious problem in rearing broilers, has been the occurrence of perosis. There is some evidence that the use of RSM in rations may result in some increase in incidence of the disorder. Holmes and Roberts (1963) noted that when rapeseed extract was fed to growing chickens there was considerable leg deformity which was reduced by the addition of vitamins and minerals. He concluded that whether or not a high incidence of perosis was due to goitrogen in RSM was still unknown. Seth and Clandinin (1973b) in a study on the incidence of perosis on RSM

diets showed that increasing levels of manganese in the ration did not decrease the incidence of perosis in broiler chickens. They also noted a higher incidence of perosis in the males than females. The difference noted may have been due to higher body weight in males as compared to females which in turn caused greater load on the leg joint and thus may have tended to cause the Achilles tendon to slip from its condyles.

EXPERIMENTS AT THE UNIVERSITY OF ALBERTA

Experiments were conducted to study:

Section I: Effects of low and high glucosinolate rapeseed meals on the productive performance, egg quality, composition of liver and incidence of hemorrhagic liver syndrome in laying birds

Section II: Effects of low glucosinolate rapeseed meals on performance in broiler chickens

SECTION I

The effects of low and high glucosinolate rapeseed meals on the productive performance, egg quality, composition of liver and incidence of hemorrhagic liver syndrome in laying birds

Status of the Problem

In recent years, the growing of rapeseed in Canada has expanded rapidly. Today, Canada is the major exporter of this oil-rich seed.

Brassica napus (Argentine) rapeseed and *Brassica campestris* (Polish) rapeseed are the two main types of rapeseed grown in Canada. Until recently, the varieties grown were relatively high in glucosinolate content. However, in 1974 Canadian plant breeders (Stefansson and Kondra, 1975) released a new variety of *B. napus* type named 'Tower', which contained only about one-eighth as much glucosinolates as older Canadian varieties of rapeseed.

Prior to the development of Tower rapeseed nutritionists in Canada (Clandinin *et al.*, 1972b) had recommended that not more than 5% of RSM from older Canadian varieties be used in rations for laying hens. With the development of the Tower variety of rapeseed, it seemed possible that higher levels of RSM may be used safely in rations for laying hens.

The following experiment was conducted to determine the maximum level of 'Tower' RSM that may be used in

laying rations without affecting egg production, egg size, egg quality and thyroid size adversely.

Experimental

Two experiments were conducted using 1260 Shaver Starcross 288 Leghorns. The birds used were raised on rations containing no RSM.

In Experiment I, two replicate groups of 70, 24-week old pullets were placed on each of the rations shown in Table 1. Experiment II was the same as Experiment I except that the number of birds in each replicate was 35. In both experiments birds were housed at a density of 1 bird per 0.25 square meters.

The rations fed (Table 1) contained varying levels of low glucosinolate RSM (prepared from the Tower variety of rape) and high glucosinolate RSM (prepared from a mixture of Midas and Torch varieties of rape). All rations were formulated to be isocaloric and isonitrogenous, with calculated ME and protein contents of 2584 kcals/kg and 16.6% respectively, by adjusting the wheat, stabilized fat and SBM contents. Feed, water, oyster shell and insoluble grit were fed *ad libitum*. Fourteen hours of light was provided daily. The duration of the experiment was 44 weeks.

Records were kept of daily egg production, average egg weight (from one days collection every week), feed consumption and mortality. Birds that died were sent to the Provincial Veterinary Laboratory, Edmonton, for

Table 1. Percentage composition of experimental rations for laying hens

Ingredient	RATION NUMBER					
	1	2	3	4	5	6
Ground wheat (13.5% protein)	49.215	46.815	46.215	45.615	45.915	44.265
Ground oats	10	10	10	10	10	10
Ground barley	10	10	10	10	10	10
Wheat shorts (17.0% protein)	5	2	1.25	0.5	2	0.5
Dehydrated alfalfa meal	2	2	2	2	2	2
Stabilized fat	1	2.5	2.875	3.25	2.5	3.25
Meat meal (53% protein)	2	2	2	2	2	2
Herring meal (72% protein)	1	1	1	1	1	1
Low glucosinolate rapeseed meal (38% protein)	-	10	12.5	15	-	-
High glucosinolate rapeseed meal (35% protein)	-	-	-	-	10	15
Soybean meal (48.5% protein)	10	3.9	2.375	0.85	4.8	2.2
Ground limestone	7	7	7	7	7	7
Calcium phosphate (18.5% Ca, 20.5% P)	1.5	1.5	1.5	1.5	1.5	1.5
Iodized salt	0.45	0.45	0.45	0.45	0.45	0.45
Manganese oxide (62% Mn)	0.025	0.025	0.025	0.025	0.025	0.025
Zinc oxide (78% Zn)	0.01	0.01	0.01	0.01	0.01	0.01
Micronutrient premix[1]	0.8	0.8	0.8	0.8	0.8	0.8

[1]Supplied the following levels per kilogram of ration: Vitamin A, 12,000 IU; Vitamin D_3, 1200 ICU; riboflavin, 3 mg; calcium pantothenate, 6 mg; niacin, 15 mg and vitamin B_{12}, 7.5 mcg.

autopsy in order to ascertain the cause of death. At 4-week intervals, specific gravity and Haugh unit values were determined on 30 eggs from each replicate in Experiment I and 15 eggs from each replicate in Experiment II, laid during one day.

At the end of the experimental period 4 birds from each replicate were selected at random, killed by cervical dislocation and weighed individually. Livers, thyroids and spleens were removed and their weights were recorded. Individual livers were also scored visually for fat on a scale from 1 to 5, a rating of 1 indicating a normal liver and a rating of 5 for a liver that appeared to have a very high fat content. Incidence of hematomas in the liver was also noted. The livers of the 4 birds from each pen were pooled, weighed, frozen and freeze-dried for further analysis.

The freeze-dried livers were weighed and the dry matter contents of the fresh livers were calculated. Samples of freeze-dried liver were analysed for protein (N x 6.25) by the AOAC (1970) method. The fat content was determined by digestion of samples of the freeze-dried liver with 6N hydrochloric acid for 2 hours, filtration, air drying and extraction of the air-dried residue with petroleum ether for 12 hours (AOAC, 1970). Samples of Tower RSM and the high glucosinolate RSM used were analysed for OZT and ITC content by the method of Appelqvist and Josefsson (1967).

Average values obtained for replicates were subjected to analyses of variance. Significance of difference were assessed by applying Duncan's Multiple Range Test (Steel and Torrie, 1960) at the 0.05 level of probability.

Results and Discussion

The combined results of Experiment I and II are presented in Tables 3, 4 and 5. Mortality during the experiments was very low and showed no treatment effects. Deaths were mainly due to a mild outbreak of coccidiosis and not to HLS.

The data presented in Table 2 indicate that the low glucosinolate meal contained only about one-tenth as much glucosinolates as the high glucosinolate meal. This, of course, resulted in considerable variation in the glucosinolate contents of the rations tested.

A decrease in hen-housed production (HHP) was observed as the level of glucosinolate in the ration increased, being lowest when 15% high glucosinolate RSM was included in the ration. Although inclusion of low glucosinolate RSM in the ration at the 15% level decreased HHP the decrease was not significantly different from that of the control. Similar observations were recorded with Hen-day production (HDP) where lowest production was recorded when 10% and 15% high glucosinolate RSM were included in the ration, while levels of up to 15% of low glucosinolate RSM resulted in HDP values which were

Table 2. Potential oxazolidinethione and isothiocyanate contents of rapeseed meals (laying expt.)

	Kind of meals	
	Tower	(Mixture) Midas and Torch
Oxazolidinethione, mg/g[1]	0.59	5.36
Isothiocyanate, mg/g[1]	0.36	4.31
Total glucosinolates, mg/g	0.95	9.67

[1]Liberated by hydrolysis of meal with myrosinase. Expressed as aglucone.

Table 3. Performance of layers fed various levels of low and high glucosinolate rapeseed meals[1,2]

Trait	RATION NUMBER 1	2	3	4	5	6	SEM
Mortality, %	1.1	1.4	2.1	4.3	4.2	3.5	1.60
Hen-housed production, %	81.6^{a}	81.6^{a}	79.1^{ab}	78.6^{abc}	76.8^{bc}	74.9^{c}	1.20
Hen-day production, %	81.8^{ab}	82.9^{a}	79.4^{bc}	79.6^{bc}	78.8^{c}	76.1^{d}	0.83
Egg Haugh unit	79.7^{a}	79.9^{a}	79.3^{a}	78.9^{a}	77.5^{b}	76.0^{c}	0.44
Egg specific gravity	1.079	1.078	1.077	1.078	1.077	1.078	0.00
Egg weight, g	59.2	59.6	59.4	59.0	59.2	58.8	0.36
Feed/doz egg, kg	1.74^{bc}	1.72^{bc}	1.76^{ab}	1.70^{c}	1.75^{abc}	1.81^{a}	0.02
Initial body weight, kg	1.52	1.53	1.52	1.51	1.50	1.51	0.01
Final body weight, kg	1.90^{a}	1.90^{a}	1.88^{ab}	1.87^{ab}	1.80^{bc}	1.72^{c}	0.03
Thyroid weight, mg/100 g body weight[3]	7.9^{b}	14.6^{b}	17.9^{b}	16.7^{b}	104.6^{a}	103.9^{a}	6.93
Liver weight, g/100 g body weight[3]	2.3	2.3	2.3	2.4	2.5	2.4	0.09
Spleen weight, mg/100 g body weight[3]	82.4	82.5	82.8	88.5	82.6	91.3	3.22

[1]Data from Experiments I and II have been combined.

[2]Row values with the same letters or no letters are not significantly different ($P<0.05$).

[3]Results based on individual chicken data.

not significantly different from that of the control. This is in agreement with the work of Clandinin et al. (1976) who showed that a level of 10% of Tower RSM in laying rations did not affect HHP adversely. Marangos et al. (1974) reported that feeding increasing levels of OZT (supplied by high OZT containing RSM) in laying rations resulted in corresponding decreases in egg production.

Egg weight and egg specific gravity were unaffected by treatment but egg Haugh unit values were influenced by the level of glucosinolate in the ration. Inclusion of up to 15% low glucosinolate RSM in the ration did not affect the egg Haugh unit values but inclusion of 10% and 15% high glucosinolate RSM in the ration caused a marked reduction in egg Haugh unit values.

While feed conversion was slightly better in the 15% low glucosinolate RSM treatment, no practical significance can be attached to this as it may have been caused by assigning too low an ME value to the low glucosinolate RSM (1760 kcals/kg) when the rations were formulated. Inclusion of up to 15% low glucosinolate RSM in rations did not cause a significant depression in final body weight although 10% and 15% high glucosinolate RSM caused marked depressions in final body weight. It was also observed that as the level of glucosinolate in the RSM increased there was a corresponding decrease in the

body weight which suggested that the depression in body weight was related to the glucosinolate content of the ration.

Statistical analysis of data for thyroid weights of the birds fed the three levels of low glucosinolate RSM and the control ration showed that the thyroid weights of the birds fed low glucosinolate RSM were significantly larger than those fed the control ration (Table 4). However when thyroid weights of birds fed the control ration, low glucosinolate and high glucosinolate rations were analysed together the thyroid weights of birds fed up to 15% low glucosinolate RSM were not significantly different from that of the control. This was due to almost sevenfold increase in size of thyroid weights of birds fed 10% and 15% high glucosinolate RSM when compared to the thyroid weights of birds fed low glucosinolate RSM (Table 3). As previously mentioned the high glucosinolate RSM contained almost 10 times as much OZT as the low glucosinolate meal (Table 2). Marangos and Hill (1976) similarly reported that thyroid weights were significantly increased with the level of RSM in the diet and that the increase was related to the level of OZT in the meal.

There was no effect of treatment on liver weight and spleen weight which is in agreement with Olomu _et al_. (1975) and contrary to the report of Marangos and Hill (1976) who indicated that liver weight increased when high OZT meals were included in the ration. Composition of the

Table 4. Comparison of low glucosinolate rapeseed meal thyroid weight data with control thyroid weight data[1,2]

	RATION NUMBER				
	1	2	3	4	SEM
Thyroid weight, mg/100 g body weight[3]	7.939[b]	14.566[a]	17.887[a]	16.658[a]	1.08

[1]Data from experiments I and II have been combined.

[2]Row values with the same letters or no letters are not significantly different ($P<0.05$).

[3]Results based on individual chicken data.

Table 5. Effect of low and high glucosinolate rapeseed meal on composition of livers and on liver fat scores[1,2]

	RATION NUMBER						
Trait	1	2	3	4	5	6	SEM
Wet weight, g[3]	41.60	40.10	41.43	39.28	42.87	41.49	1.85
Dry matter, %	25.20	24.05	24.98	25.43	24.22	24.44	0.49
Protein, %[4]	70.83	74.51	73.00	71.84	74.94	74.40	1.37
Fat, %[4]	19.88	15.45	17.63	18.78	14.57	14.74	1.46
Fat score[5]	2.56	2.25	2.31	2.38	2.31	2.62	0.15

[1] Data from experiments I and II have been combined.

[2] All row values are not significantly different ($P<0.05$).

[3] Average weight of 4 birds.

[4] Dry matter basis.

[5] Results based on individual chicken data.

liver and liver fat scores (Table 5) showed no significant difference in wet weight, level of dry matter, protein or fat and visual fat score between the different treatments. Of the 96 birds killed at the end of the experiment only 3 birds showed hemorrhages in the liver. Of the 3 birds with hemorrhages in the liver, 2 were from the birds fed 15% Tower RSM and 1 from the birds fed 12.5% Tower RSM.

Summary

Two experiments were conducted in which duplicate groups of Shaver Starcross 288 pullets were fed rations containing varying levels of low glucosinolate or high glucosinolate RSM for a period of 44 weeks. Records were kept of mortality, body weight, egg production, egg weight, egg quality and feed consumption. At the end of the experiment 4 birds from each replicate selected at random, were killed and thyroids, livers and spleens were removed and weighed. Livers were scored visually for fat and hemorrhagic liver syndrome. Livers were also freeze-dried and analyzed for dry matter, protein and fat percentages. Results obtained indicated that:

1. Mortality was low and showed no ration treatment effects.
2. Inclusion of up to 15% of low glucosinolate RSM in the ration did not significantly decrease egg production while inclusion of 10% or 15% of high glucosinolate RSM in the ration reduced egg production.
3. Egg weight and egg specific gravity were unaffected by ration treatment. Levels of up to 15% low glucosinolate

RSM did not affect egg Haugh unit values adversely, but, inclusion of 10% or 15% of high glucosinolate RSM in the ration resulted in reduced egg Haugh unit values.

4. Inclusion of up to 15% of low glucosinolate RSM in the ration did not cause a depression in final body weight, however inclusion of 10% or 15% of high glucosinolate RSM caused marked depression of final body weight.

5. Thyroid weights of the birds fed rations containing low or high glucosinolate RSM were significantly larger than those of birds fed the control ration which contained no RSM. Thyroid weights of the birds fed rations containing high glucosinolate RSM were almost seven times those of the birds fed rations containing low glucosinolate RSM.

6. Weight of liver and weight of spleen were unaffected by ration treatment. The content of dry matter, protein and fat in liver was also unaffected by ration treatment. Incidence of HLS was negligible.

7. Feed conversion was poorest with the 15% high glucosinolate RSM ration while the other ration treatments did not show much variation.

On the basis of the results obtained in this study it would appear that up to 15% of low glucosinolate RSM

(produced from Tower rapeseed) may be included in laying rations without adversely affecting the productive traits of the birds.

SECTION II

Effects of low glucosinolate rapeseed meals on performance in broiler chicken

Status of the Problem

In numerous studies conducted in Canada it has been found that 15% high glucosinolate type RSM may be used in broiler rations, as a replacement for SBM (Clandinin *et al.*, 1972b). Use of higher levels in rations for broilers has been found to depress growth and reduce efficiency of feed conversion. The adverse effects reported have frequently been attributed to the presence of high levels of glucosinolates in RSM.

In 1974, a low glucosinolate variety of rapeseed, called Tower, was developed from *B. napus* rapeseed and licensed for growing in Canada (Stefansson and Kondra, 1975). Studies involving RSM produced from this variety of seed showed that broiler rations could contain up to 20% of Tower RSM without adversely affecting productive traits.

In more recent years there has been a concerted effort by rapeseed breeders to develop a yellow seeded type of rapeseed. It is known that the yellow seed coat is thinner than the brown seed coat and, as a consequence produces RSM of lower fibre content. In addition yellow seeded rapeseed produces a RSM that has a pleasing light appearance which permits feed formulators greater freedom to alter their formulas without visual changes in the

finished feeds. A yellow seeded B. campestris cultivar CZY3-1821 (later named Candle) developed by the crossing of low glucosinolate B. campestris rapeseed with yellow seeded mustard was licensed for growing commercially in Canada in 1977 (Downey and Klassen, 1977). Since there was a limited amount of information available on the use of low glucosinolate RSMs in broiler rations an experiment was conducted to compare the performance of broilers fed varying levels of meals from Candle and Tower rapeseed.

Experimental

Nine hundred and sixty day-old Hubbard broiler chicks (480 males and 480 females) were used in the study. The chicks were wing-banded and randomly allotted (20 males and 20 females) into 24 groups. Each group occupied a radiant floor-heated pen 1.5 m x 4.3 m in size.

Three pens of chicks were fed each of the 8 rations shown in Table 6. Rations 1 and 8 were control rations based on SBM while rations 2 to 4 and 5 to 7, respectively contained varying levels of Tower and Candle RSM. All rations were designed to be isocaloric and isonitrogenous, with calculated ME value of 2875 kcal/kg and protein percentage of 22.8. The calculated calcium, phosphorus and inorganic phosphorus levels were 1.00, 0.76 and 0.48% respectively. Samples of the rations were sent to the Soil and Feed Testing Laboratory, Alberta Agriculture, Edmonton, for protein, calcium and phosphorus analysis. Samples of

Table 6. Percentage composition of experimental rations[1] for broiler chicks

Ingredients	RATION NUMBER							
	1	2	3	4	5	6	7	8
Ground wheat (13.5% protein)	66.67	60.67	54.27	48.07	60.37	54.07	47.77	66.67
Stabilised fat	1.0	3.5	6.0	8.5	3.5	6.0	8.5	1.0
Dehydrated alfalfa meal	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Meat meal (50% protein)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Ground limestone	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Dicalcium phosphate (18% Ca - 21% P)	0.8	0.6	0.4	0.2	0.6	0.4	0.2	0.8
Iodized salt (70 ppm I)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Manganese oxide (62% Mn)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Zinc oxide	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Micro ingredients[2]	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Soybean meal (47.5% protein)	25.0	18.9	12.8	6.7	19.0	13.0	7.0	25.0
Tower rapeseed meal (37.7% protein)	-	10.0	20.0	30.0	-	-	-	-
Candle rapeseed meal (36.5% protein)	-	-	-	-	10.0	20.0	30.0	-
Chemical Analysis								
Protein, %	22.9	22.50	22.9	23.2	22.5	21.9	21.9	22.9
Calcium, %	1.10	0.96	1.00	0.95	1.00	0.96	0.97	1.20
Phosphorus, %	0.74	0.70	0.74	0.72	0.72	0.72	0.72	0.74

[1]Calculated analyses for rations showed average values of 2785 kcal/kg for ME, 22.8% protein, 1.00% calcium, 0.76% total phosphorus and 0.48% inorganic phosphorus.

[2]Supplied the following levels per kg of ration: Vitamin A, 6000 IU; vitamin D_3, 1200 ICU; vitamin E, 10 IU; menadione sodium bisulfate, 1 mg; riboflavin, 4 mg, calcium pantothenate, 5 mg; niacin, 20 mg; choline chloride, 60 mg; folic acid, 1 mg; DL-methionine, 500 mg; biotin, 200 mcg; vitamin B_{12}, 10 mcg; selenium, 0.1 mg; amprol (25% amprolium) 500 mg.

the Tower and Candle RSM used in the rations were analysed for potential OZT and ITC by the method of Appelqvist and Josefsson (1967).

Feed and water were supplied ad libitum. Twenty-four hours of light was provided during the first 3 days of brooding and 16 hours of light per day thereafter. The duration of the experiment was 8 weeks.

Daily records of mortality were kept. The birds were weighed individually at 4 and 8 weeks of age and group weights were recorded at 6 weeks of age. A record of feed consumption at 4,6 and 8 weeks was kept and feed/gain ratios were calculated. Incidence of perosis in each group at 4, 6 and 8 weeks of age was recorded.

At the end of the experiment, 8 birds from each pen, consisting of 4 males and 4 females were killed by cervical dislocation and thyroids were removed and weighed. Thyroid to body weight ratios were calculated. Incidence of fatty and hemorrhagic liver was also noted.

The data obtained were subjected to analyses of variance. Significance of difference was assessed by applying Duncan's Multiple Range Test (Steel and Torrie, 1960) at the 0.05 level of probability.

Results and Discussion

Results of analysis of the Tower and Candle RSMs for potential OZT and ITC (Table 7) indicated that the low glucosinolate meals contained approximately one-tenth as much glucosinolate as reported by Bell and Jeffers

Table 7. Potential oxazolidinethione and isothiocyanate contents of rapeseed meals (broiler expt)

	Kind of meals	
	Tower	Candle
Oxazolidinethione, mg/g[1]	0.78	0.53
Isothiocyanate, mg/g[1]	0.27	0.31
Total glucosinolates, mg/g	1.05	0.84

[1]Liberated by hydrolysis of meal with myrosinase. Expressed as aglucone.

(1976) to be present in Canadian high glucosinolate type RSM. The data also indicated that Candle RSM was somewhat lower in glucosinolates than Tower RSM. This is understandable, since Candle is a *B. campestris* type rapeseed while Tower is a *B. napus* type rapeseed. In general, *B. campestris* varieties tend to have lower levels of total glucosinolates than *B. napus* varieties (Bell and Jeffers, 1976).

The performance of the birds on the different treatments at 4, 6 and 8 weeks of age is summarized in Table 8.

The rate of growth of the broilers was not affected by the levels of RSM used. Average body weights of the groups receiving 10, 20 or 30% of either Tower or Candle RSM did not differ significantly at 4, 6 or 8 weeks of age from the body weights of the birds fed the control ration based on SBM as the source of supplementary protein. This is in general agreement with other information on the use of low glucosinolate RSMs in broiler rations. Clandinin *et al*. (1976) in a review article reported that Slinger (unpublished data) had noted that inclusion of 20% of low glucosinolate RSM (from Tower rapeseed) in rations for broilers had no adverse effects on growth to 4 weeks of age and that in their own studies inclusion of 15% of low glucosinolate RSM (double zero) likewise had no adverse effects on growth to 8 weeks.

Efficiency of feed utilization was not affected by the

Table 8. Performance of broilers fed rations containing various levels of low glucosinolate rapeseed meals[1]

Trait	RATIONS								
	1 Soy	2 Tower	3 Tower	4 Tower	5 Candle	6 Candle	7 Candle	8 Soy	
	Control	10%	20%	30%	10%	20%	30%	Control	SEM
4 Weeks									
Weight, g	636.6	630.6	640.6	595.5	650.2	652.6	621.1	596.5	14.10
Feed efficiency, g/g body weight	1.70	1.71	1.69	1.68	1.65	1.63	1.69	1.67	0.03
Mortality, %	1.7	4.2	4.2	0.8	2.5	5.0	5.0	3.3	1.21
Perosis, %	0	0	0	0	0	2.5	3.3	0	1.18
6 Weeks									
Weight, g	1303.4	1320.8	1326.1	1273.7	1306.8	1309.7	1265.7	1247.5	18.85
Feed efficiency, g/g body weight	1.91	1.91	1.89	1.91	1.86	1.89	1.89	1.88	0.04
Mortality, %	1.7	4.2	4.2	0.8	2.5	5.0	5.0	3.3	1.21
Perosis, %	0	0	0.8	0.8	2.5	2.5	2.5	0	0.83
8 Weeks									
Weight, g	1996.0	2013.9	1992.4	1974.2	2001.4	2015.3	1939.6	1863.6	41.70
Feed efficiency, g/g body weight	2.22	2.20	2.17	2.16	2.15	2.16	2.14	2.26	0.03
Mortality, %	1.7	4.2	4.2	0.8	2.5	5.0	5.0	4.2	1.2
Perosis, %	0.8	0	3.3	4.2	0	2.5	1.7	0	1.18
Thyroid weight, (mg/100 g body weight)[2]	10.1^{ab}	12.9^{bc}	16.9^{de}	17.6^{e}	12.6^{abc}	14.3^{cd}	15.1^{de}	9.7^{a}	0.97

[1]Row values with the same letters or no letters are not significantly different.

[2]Results based on individual chicken data.

treatments used. While minor numerical differences in feed conversion were noted, none of the differences proved to be significantly different ($P<0.05$). These results suggest that the ration must have been close to being isocaloric. The results agree with those of Slinger (1976b) who reported no significant differences in feed/gain ratios at 4 weeks of age when levels of up to 40% of low glucosinolate RSM (1788) were fed to growing chickens. Likewise, Clandinin et al. (1976) found that inclusion of 15% of low glucosinolate RSM in rations for broilers had no effect on feed conversion at 8 weeks of age.

Levels of mortality in the groups were generally low. Most of the mortality occurred during the 0-4 weeks period. While some variability in mortality levels between groups was noted there was no significant differences due to treatment at 4, 6 or 8 weeks of age. Mortality that was observed during the first week of the experiment was caused by dehydration of birds. No losses from HLS was noted.

Incidence of perosis was not significantly affected by the treatments used. The occurrence of the disorder, however, was higher in the groups fed 20 or 30% low glucosinolate RSMs as compared to the control or those receiving 10% low glucosinolate meals. In addition the number of birds affected increased between 4 and 8 weeks of age. It is possible that higher incidence at 8 weeks of age was related to body weight. The importance of body weight as

a factor influencing this condition is emphasized by the fact that incidence was higher in males than females. This observation agrees with the work of Creek et al. (1960) who demonstrated that body weight plays a role in the incidence of perosis. It also agrees with the report of Seth and Clandinin (1973b) who noted a higher incidence of perosis in male than in female broiler chickens which was associated with the greater body weight of the males as compared to that of the females.

The addition of varying levels of RSM to broiler rations resulted in increased thyroid size. The results indicated that thyroid to body weight ratios were lower on the control rations than on the treatment groups. It was apparent that as the level of either Tower or Candle RSM in the ration was increased, thyroid to body weight ratios increased. It was, however observed that corresponding levels of Candle RSM produced slightly lower thyroid to body weight ratios that similar levels of Tower RSM indicating that level of potential OZT in the meals influenced the thyroid size. As indicated previously (Table 7), Candle RSM has a slightly lower level of potential OZT than Tower RSM. The thyroid to body weight ratio of the birds fed 30% Candle RSM was similar to the thyroid to body weight ratio of the birds fed 20% Tower RSM and slightly smaller than that of birds fed 30% Tower RSM, although these differences did not prove to be significant at $P<0.05$ level.

No evidence of fatty liver or HLS was noted in any of the birds examined. Appearance of the livers from broilers fed the various levels of Tower or Candle RSMs was similar to that noted in the controls.

Summary

Triplicate groups of 20 male and 20 female day-old Hubbard broiler chicks were fed rations containing 0, 10, 20 and 30% of low glucosinolate RSMs (prepared from Tower and Candle rapeseed). The rations were formulated to be isocaloric and isonitrogenous. Records were kept on mortality, body weight, feed conversion and incidence of perosis. Thyroid size, incidence of fatty liver syndrome and HLS at 8 weeks were also recorded. The results obtained indicated that:

1. Inclusion of up to 30% of low glucosinolate meals in broiler rations resulted in weight gains equivalent to those of birds fed a SBM control ration.
2. Efficiency of feed utilization was not affected by any of the treatments at 4, 6 or 8 weeks of age.
3. Mortality was low throughout the experiment and was not influenced by the treatments used.
4. The incidence of perosis was higher in birds fed rations containing the higher levels of RSMs. Incidence also tended to increase with increasing age of the bird.

5. Thyroid to body weight ratios of birds fed RSM increased compared to the controls as the level of RSM in the rations was increased.
6. No incidence of fatty or hemorrhagic liver syndrome was noted.

These results suggest that at least 20% of low glucosinolate RSM prepared from Tower or Candle rapeseed may be used in broiler rations without affecting productive performance.

BIBLIOGRAPHY

AKIBA, Y. and T. MATSUMOTO. 1973. Thyroid function of chicks after withdrawal of (-)-5-vinyl-2-oxazolidinetione, a goitrogen in rapeseed. Poultry Sci. 52: 562-567.

ALLEN, C.E. and D.S. DOW. 1952. The biological assessment of the value of rapeseed oil meal as a dietary component. Sci. Agric. 32: 403-410.

APPELQVIST, L.A. and E. JOSEFSSON. 1967. Method for quantitative determination of isothiocyanates and oxazolidinethiones in digests of seed meals of rape and turnip rape. J. Sci. Fd Agric. 18: 510-519.

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS. 1970. Official methods of analysis., 11th ed. Washington, D.C., A.O.A.C.

ASTWOOD, E.B., M.A. GREER and M.G. ETTLINGER. 1949. L-5-Vinyl-2-thioxazolidione, an antithyroid compound from yellow turnip and from Brassica seeds. J. Biol. Chem. 181: 121-130.

BELL, J.M. and H.F. JEFFERS. 1976. Variability in the chemical composition of rapeseed meal. Can. J. Anim. Sci. 56: 269-273.

BLAKELY, R.M. and R.W. ANDERSON. 1948. Studies with rapeseed oilcake meal. II. The effect of the inclusion of protamone in the diet, on the thyroid enlargement induced by the feeding of rape-seed oilcake meal to turkey poults. Sci. Agric. 28: 398-402.

BOLTON, W., T.C. CARTER and R.M. JONES. 1976. The hen's egg: genetics of taints in eggs from hens fed on rapeseed meal. Br. Poultry Sci. 17: 313-320.

BRAGG, D.B. 1974. Mineral content and mineral availability of various rapeseed meals. Research on Rapeseed-Seed, Oil and Meal. Rapeseed Assoc. of Canada. Publ. 35. pp. 106-107.

CLANDININ, D.R., R. RENNER and A.R. ROBBLEE. 1959. Rapeseed oil meal studies. 1. Effects of variety of rapeseed, growing environment and processing temperatures on the nutritive value and chemical composition of rapeseed oil meal. Poultry Sci. 38: 1367-1372.

CLANDININ, D.R. and L. BAYLY. 1960. Rapeseed oil meal studies. 2. Effects of feeding rapeseed oil meal on the structure of the thyroid glands and chickens. Poultry Sci. 39: 1239-1240.

CLANDININ, D.R. and E.W. TAJCNAR. 1961. 1. Effects of variations in cooking and conditioning temperatures used during expeller processing of rapeseed on the fat and lysine content of rapeseed oil meals. Poultry Sci. 40: 291-293.

CLANDININ, D.R. and L. BAYLEY. 1963. Effect of variety and growing conditions on the protein and amino acid composition of rapeseed. Can. J. Anim. Sci. 43: 65-67.

CLANDININ, D.R. 1966. Feeding value of rapeseed meal for poultry. Rapeseed meal for livestock and poultry.

A Review. Canada Dept. Agr. Publ. no. 1257. pp. 81-92.

CLANDININ, D.R. and A.R. ROBBLEE. 1966. Rapeseed meal for poultry. A Review. World's Poultry Sci. J. 22: 217-232.

CLANDININ, D.R., L. BAYLY and A. CABALLERO. 1966. Rapeseed meal studies. 5. Effects of (±)-5-vinyl-2-oxazolidinethione, a goitrogen in rapeseed meal, on the rate of growth and thyroid function of chicks. Poultry Sci. 45: 833-838.

CLANDININ, D.R. 1967. Nutrient composition of expeller, prepress-solvent, and solvent processed rapeseed meals. Poultry Sci. 46: 1596-1597.

CLANDININ, D.R. and J. HEARD. 1968. Tannins in prepress-solvent and solvent processed rapeseed meal. Poultry Sci. 47: 688.

CLANDININ, D.R., S.J. SLINGER, and J.M. BELL. 1972a. Composition of Canadian rapeseed meal. Canadian Rapeseed Meal in Poultry and Animal Feeding. Rapeseed Assoc. of Canada. Publ. 16. pp. 8-10.

CLANDININ, D.R., A.R. ROBBLEE and S.J. SLINGER. 1972b. Rapeseed meal for poultry. Canadian Rapeseed Meal in Poultry and Animal Feeding. Rapeseed Assoc. of Canada. Publ. 16. pp. 11-15.

CLANDININ, D.R., Z. HAWRYSH, J. HOWELL, J.A. HANSON, R.G. CHRISTIAN and G. MILNE. 1974. Problems associated

with the feeding of rations containing rapeseed meal to laying chickens. Proceedings 4. Internationaler Rapskongress. Giessen. pp. 463-470.

CLANDININ, D.R., A.R. ROBBLEE and K. DARLINGTON. 1976. A review of research on the use of low glucosinolate type rapeseed meal in rations for poultry. 55th Annual Feeders' Day Report. Dept. of Animal Science, University of Alberta, Edmonton, Alberta. pp. 53-57.

CLANDININ, D.R., A.R. ROBBLEE, Y.K. GOH, K. DARLINGTON and G.R. Milne. 1977. Use of rapeseed meal in rations for laying chickens. Rapeseed Oil, Meal and By-Product Utilization. Rapeseed Assoc. of Canada. Publ. 45. pp. 177-190.

CREEK, R.D., H.E. PARKER, S.M. HAUGE, F.N. ANDREWS and C.W. CARRICK. 1960. The influence of body weight on the experimental production of perosis by manganese deficiency. Poultry Sci. 39: 96-98.

DAXENBICHLER, M.E., C.H. VAN ETTEN and I.A. WOLFF. 1966. (S)-and (R)-1-Cyano-2-hydroxy-3 butene from myrosinase hydrolysis of epi-progoitrin and progoitrin. Biochem. 5: 692-697.

DOW, D.S. and C.E. ALLEN. 1954. Rapeseed oil meal in broiler rations with observations on the nature and control of its metabolic inhibitors. Can. J. Agr. Sci. 34: 607-613.

DOWNEY, R.K. and A.J. KLASSEN. 1977. Rapeseed improvement through plant breeding. Rapeseed Oil, Meal and By-

Product Utilization. Rapeseed Assoc. of Canada. Publ. 45. pp. 4-11.

FANGAUF, R. and A. HAENSEL. 1938. Rye bran, dried brewers' grains, malt coombs and ground rape seed cake as food for hens. Arch. Geflugelk. 12: 149-158.

FINLAYSON, A.J. 1977. The chemistry of the constituents of rapeseed meal. Rapeseed Oil, Meal and By-Product Utilization. Rapeseed Assoc. of Canada. Publ. 45. pp. 124-136.

FROLICH, A. 1952. Experiments with Swedish rapeseed meal in growing chicks and egg laying hens. Kungl. Lantbrukshogskolans Ann. 19: 205-207.

GIOVANNETTI, P. and J.M. BELL. 1971. Characteristics of rapeseed and rapeseed meals. Research on Rapeseed Meal. Rapeseed Assoc. of Canada. pp. 1-14.

GOH, Y.K. and D.R. CLANDININ. 1977. Transfer of ^{125}I to eggs from hens fed rations containing high and low glucosinolate rapeseed meals. Br. Poultry Sci. 18: 705-710.

GREER, M.A. 1956. Isolation from rutabaga seed of progoitrin, the precursor of the naturally occurring antithyroid compound, goitrin (L-5-vinyl-2-thioxazolidone). J. Am. Chem. Soc. 78: 1260-1261.

GREER, M.A., J.W. KENDALL and M. SMITH. 1964. Antithyroid compounds. In R. Pitt-River and W.R. Trotter, The Thyroid Gland Vol. 1, Butterworths, London. pp. 357-389.

HALL, S.A. 1972. Lysis of hepatic reticulin. An unusual les in laying fowls possibly associated with rape-seed meal. Vet. Record 91: 495.

HALL, S.A. 1974. A hepatosis of laying fowls characterised by an apparent lysis of reticulin and massive liver haemorrhage. Vet. Record 94: 42-44.

HILL, R. and A. MARANGOS. 1974. The effects of a range of rapeseed meals and a mustard seed meal on the health and production of hybrid laying pullets. XV World's Poultry Congress Report, New Orleans, U.S.A. pp. 608-609.

HOBSON-FROHOCK, A., D.G. LAND, N.M. GRIFFITHS and R.F. CURTIS. 1973. Egg Taints: Association with trimethyl-amine. Nature 243: 304-305.

HOBSON-FROHOCK, A., R.G. FENWICK, D.G. LAND, R.F. CURTIS and A.L. GULLIVER. 1975. Rapeseed meal and egg taint. Br. Poultry Sci. 16: 219-222.

HOLMES, W.B. and R. ROBERTS. 1963. A perotic syndrome in chicks fed extracted rape seed meal. Poultry Sci. 42: 803-809.

JACKSON, N. 1969. Toxicity of rapeseed meal and its use as a protein supplement in the diet of two hybrid strains of caged laying hens. J. Sci. Fd Agric., 20: 734-740.

JACKSON, N. 1970. Algerian and French rapeseed meals as a protein source for caged laying hens, with obser-vations on their toxic effects. J. Sci. Fd Agric., 21: 511-516.

JOSEFSSON, E. 1972. Nutritional value and use of rapeseed meal. Rapeseed - Cultivation, composition, processing and utilization. Ed. L.A. Appelqvist and R. Ohlson. Elsevier Publishing Company, Amsterdam, London, New York. pp. 354-377.

JURD, L. and T.A. GEISSMAN. 1956. Absorption spectra of metal complexes of flavanoid compounds. J. Org. Chem. 21: 1395-1401.

KENNEDY, T.H. and H.D. PURVES. 1941. Studies on experimental goitre. 1. The effect of Brassica seed diets on rats. Brit. J. Exper. Path. 22: 241-244.

KJAER, A. 1960. The chemistry of organic natural products. Springer-Verlag, Vienna. pp. 122.

KLAIN, G.J., D.C. HILL, H.D. BRANION and J.A. GRAY. 1956. The value of rapeseed oil meal and sunflower seed oil meal in chick starter rations. Poultry Sci. 35: 1315-1326.

KRATZER, F.H., P.N. DAVIS, D.E. WILLIAMS and B.J. MARSHALL. 1954. Factors influencing the growth of chicks and poults fed rations containing rapeseed oil meal. J. Nutr. 53: 407-418.

LESLIE, A.J. and J.D. SUMMERS. 1975. Amino acid balance of rapeseed meal. Poultry Sci. 54: 532-538.

LODHI, G.N., R. RENNER and D.R. CLANDININ. 1969a. Studies on the metabolizable energy of rapeseed meal for growing chickens and laying hens. Poultry Sci. 48: 964-970.

LODHI, G.N., R. RENNER and D.R. CLANDININ. 1969b. Available carbohydrate in rapeseed meal and soybean meal as determined by a chemical method and a chick bioassay. J. Nutr. 99: 413-418.

LODHI, G.N., D.R. CLANDININ and R. RENNER. 1970. Factors affecting the metabolizable energy value of rapeseed meal. 1. Goitrogens. Poultry Sci. 49: 289-294.

MARANGOS, A., R. HILL, B.M. LAWS and D. MUSCHAMP. 1974. The influence of three rapeseed meals and a mustard seed meal on egg and broiler production. Br. Poultry Sci. 15: 405-414.

MARANGOS, A. and R. HILL. 1975. The use of rapeseed meal as a protein supplemt in poultry and pig diets. Vet. Record 96: 377-380.

MARANGOS, A.G. and R. HILL. 1976. The use of rapeseed meals and a mustard seed meal as a protein source in diets for laying pullets. Br. Poultry Sci. 17: 643-653.

MARCH, B.E., J. BIELY and R. SOONG. 1975. The effects of rapeseed meal fed during the growing and/or laying periods on mortality and egg production in chickens. Poultry Sci. 54: 1875-1882.

MILLER, W.S., A. EWINS and L.G. CHUBB. 1972. Egg Taints. Vet. Record. 91: 632-633.

MOMCILOVIC, B. and B.G. SHAH. 1976. Femur zinc, magnesium, and calcium in rats fed Tower rapeseed (Brassica napus) protein concentrate. Nutr. Reports International.

13: 135-142.

MOTZOK, I. 1974. Factors affecting the bioassay procedure for available phosphorus in rapeseed meal. Research on Rapeseed - Seed, Oil and Meal. Rapeseed Assoc. of Canada. Publ. 35. pp. 100-105.

MOTZOK, I. 1976. Availability of phosphorus, zinc and manganese in rapeseed meal. Research on Rapeseed - Seed, Oil, Meal and Meal Fractions. Rapeseed Assoc. of Canada. Publ. 40. pp. 65-74.

NAKAYA, T., S. TAGAMI, T. KUCHII. 1968. The feeding value of rapeseed oilmeal for broiler. Japanese Poultry Sci. 5: 176-184.

NATIONAL ACADEMY OF SCIENCES-NATIONAL RESEARCH COUNCIL - Nutrient requirements of poultry. Sixth revised edition, 1971.

NWOKOLO, E.N., D.B. BRAGG and W.D. KITTS. 1976. Availability of amino acids from palm kernel, soybean, cottonseed and rapeseed meal for the growing chick. Poultry Sci. 55: 2300-2304.

OLOMU, J.M., A.R. ROBBLEE and D.R. CLANDININ. 1974. Effects of processing and amino acid supplementation on the nutritive value of rapeseed for broilers. Poultry Sci. 53: 175-184.

OLOMU, J.M., A.R. ROBBLEE, D.R. CLANDININ and R.T. HARDIN. 1975. Effects of Span rapeseed meal on productive performance, egg quality, composition of liver and hearts and incidence of 'fatty livers' in laying

hens. Can. J. Anim. Sci. 55: 71-75.

OVERFIELD, N.D. and H.A. ELSON. 1975. Dietary rapeseed meal and the incidence of tainted eggs. Br. Poultry Sci. 16: 213-217.

PERSMARK, U. 1972. Analysis of rapeseed oil. Rapeseed - Cultivation, composition, processing and utilization. Ed. L.A. Appelqvist and R. Ohlson. Elsevier Publishing Company, Amsterdam, London, New York. pp. 174-197.

PETIT, J.H., S.J. SLINGER, E.V. EVANS and F.N. MARCELLUS. 1944. The utilization of sunflower seed oil meal, wheat distillers' dried grains and rapeseed oil meal in poultry rations. Sci. Agric. 24: 201-213.

PURVES, H.D. 1943. Studies on experimental goitre. iv. The effect of di-iodotyrosine and thyroxine on the goitrogenic action of Brassica seeds. Br. J. Exp. Path. 24: 171-173.

RAO, P.V. and D.R. CLANDININ. 1970. Effect of method of determination on the metabolizable energy value of rapeseed meal. Poultry Sci. 49: 1069-1974.

RAO, P.V. and D.R. CLANDININ. 1972. Role of protein content, nitrogen absorbability and availability of carbohydrates in rapeseed meal on its metabolizable energy value for chicks. Poultry Sci. 51: 2001-2006.

RENNER, R., D.R. CLANDININ and A.R. ROBBLEE. 1955. Factors affecting the nutritive value of rapeseed oil meals. Poultry Sci. 34: 1233 (abstract).

ROOS, A.J. and D.R. CLANDININ. 1975. Transfer of ^{125}I to eggs in hens fed on diets containing rapeseed meal. Br. Poultry Sci. 16: 413-415.

RUTKOWSKI, A. 1971. The feed value of rapeseed meal. J. Amer. Oil Chem. Soc. 48: 1260-1261.

SELL, J.L. 1966. Metabolizable energy of rapeseed meal for the laying hen. Poultry Sci. 45: 854-856.

SETH, P.C.C. and D.R. CLANDININ. 1973a. Metabolizable energy value and composition of rapeseed meal and of fractions derived therefrom by air-classification. Br. Poultry Sci. 14: 499-505.

SETH, P.C.C. and D.R. CLANDININ. 1973b. Effect of including rapeseed meal in the ration of broiler type chickens on the incidence of perosis and the ineffectiveness of supplemental manganese. Poultry Sci. 52: 1158-1160.

SETH, P.C.C., D.R. CLANDININ and R.T. HARDIN. 1975. In vitro uptake of zinc by rapeseed meal and soybean meal. Poultry Sci. 54: 626-629.

SIBBALD, I.R. and S.J. SLINGER. 1963. Factors affecting the metabolizable energy content of poultry feeds. 12. Protein quality. Poultry Sci. 42: 707-710.

SLINGER, S.J. 1976a. 'Hemorrhagic Liver Syndrome' in laying hens on diets supplemented with rapeseed products. Research on Rapeseed-Seed, Oil, Meal and Meal Fractions. Rapeseed Assoc. of Canada. Publ. 40. pp. 84-85.

SLINGER, S.J. 1976b. Effects of feeding Span and 'Double Low' rapeseed meals on performance of poultry. Research on Rapeseed-Seed, Oil, Meal and Meal Fractions. Rapeseed Assoc. of Canada. Publ. 40. pp. 89-91.

SMITH, T.K. and L.D. CAMPBELL. 1976. Rapeseed meal glucosinolates: metabolism and effect on performance in laying hens. Poultry Sci. 55: 861-867.

STEEL, R.G.D. and J.H. TORRIE. 1960. Principles and procedures of statistics. McGraw-Hill Book Company Inc., New York, Toronto, London.

STEFANSSON, B.R. and Z.P. KONDRA. 1975. Tower summer rape. Can. J. Plant Sci. 55: 343-344.

SUMMERS, J.D., G. RAJARATNAM and W.F. PEPPER. 1971. Evaluation of rapeseed meal as a protein supplement for laying hen diets. Poultry Sci. 50: 1382-1386.

TAO, R., R.J. BELZILE and G.J. BRISSON. 1971. Amino acid digestibility of rapeseed meal fed to chickens: effects of fat and lysine supplementation. Can. J. Anim. Sci. 51: 705-709.

TURNER, C.W. 1946. Effect of rape seed on the thyroid of the chick. Poultry Sci. 25: 186-187.

TURNER, C.W. 1948. Effect of rape seed oil meal on the thyroid of the chick. Poultry Sci. 27: 118-120.

VAN ETTEN, C.H., M.E. DAXENBICHLER and I.A. WOLFF. 1969. Natural glucosinolates (thioglucosides) in foods and feeds. J. Agr. Food Chem. 17: 483-491.

VIRTANEN, A.I. 1965. A review. Studies on organic sulphur compounds and other labile substances in plants. Phytochemistry 4: 207-228.

VOGT, H., H.-J. SCHUBERT and K. STUTE. 1967. Feed value and application of rapeseed oil meal in poultry feeding. Arch. Geflugelk. 31: 225-244.

VOGT, H. and H.-J SCHUBERT. 1969. Feeding value and use of rapeseed meal in feeding poultry. 2. Start of use at different ages and the effect on thyroid development. Arch Geflugelk. 33: 42-46.

VOGT, H., H.-J SCHUBERT, K. STUTE and W. RAUCH. 1969. Feeding value and use of rapeseed meal in feeding poultry. 3. Rapeseed meal for laying hens. Arch. Geflugelk. 33: 119-124.

VONDELL, J.H. 1932. Is the production of 'Off Flavor' eggs an individual characteristic? Poultry Sci. 11: 375 (abstract).

VONDELL, J.H. 1948. Detection of chickens laying 'fishy eggs'. Poultry Sci. 27: 244-245.

YAMASHIRO, S., M.K. BHATNAGAR, J.R. SCOTT and S.J. SLINGER. 1975. Fatty haemorrhagic liver syndrome in laying hens on diets supplemented with rapeseed products. Res. in Vet. Sci. 19: 312-321.

YOSHIDA, M., H. HOSHII and H. MORIMOTO. 1969. Nutritive value of rape seed meal for poultry. Japanese Poultry Sci. 6: 30-35.